

Molecular gas in QSO host galaxies

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Abstract

We present the results of a survey for CO line emission from a sample of nearby QSO hosts taken from the Hamburg/ESO survey (HES) and the Véron-Cetty and Véron quasar catalogue. From a total of 39 observed sources we clearly detected 5 objects with $>10\sigma$ signals (HE 0108-4743, HE 0224-2834, J035818.7-612407, HE 1029-1831, HE 2211-3903). Further 6 sources show marginal detections on the 2σ level.

Key words: galaxies: ISM, quasars: general, galaxies: active, radio lines: galaxies

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1. Introduction

Studies of molecular gas in the host galaxies of QSOs and high rank Seyfert 1 galaxies are essential for the understanding of the star formation in and fueling of the central engines. Especially the nearby QSOs ($z \leq 0.1$) represent an important link between the cosmologically local AGN and the high redshift, high luminosity QSOs ($z \geq 0.5$). Observations of galaxies hosting AGN remain challenging, even with state-of-the-art instrumentation. Studies of this kind require exceptionally high spatial resolutions and sensitivities to be able to separate the nuclear component from the faint contribution of the underlying galaxy. But even with the highest resolutions feasible, a detailed analysis of the distribution and kinematics of the molecular gas component is possible only for the closest objects. There are only few cases

which have been investigated so far, among them 3C48 (for details cf. Zuther et al., this vol., and references therein). For studies of further objects the identification of suitable sources is mandatory. Until today, only a few surveys have been carried out, which are dedicated to the detection of molecular gas in QSOs (e.g. Evans et al., 2001, 2005; Scoville et al., 2003).

2. The Sample

The sources in our sample were selected from the Hamburg/ESO survey (HES) (Wisotzki et al., 2000) for bright QSOs and the Véron-Cetty and Véron quasar catalogue (Véron-Cetty and Véron, 2001). Unlike preceding surveys, HES does not discriminate against extended sources, thus enabling the study of host galaxies. The only se-

lection criterion for the nearby QSO sample was the cosmological distance: only objects with a redshift $z < 0.060$ were chosen. This redshift limit ensures the observability of the important diagnostic CO(2-0) rotation vibrational band head absorption line, which is then still accessible in the K-band (cf. Fischer et al., this vol.). The sample consists of 63 sources. It is entirely based on a volume limit and not based on a FIR flux selection criterion.

3. Results

We scanned 39 members of the nearby QSO sample for millimetric CO emission so far. The primary goal was to identify the CO brightest objects for high resolution interferometric followup observations. These initial measurements were carried out in part with the BIMA array, in part with the SEST 15m single-dish telescope and resulted in 5 detections. Another 6 sources show marginal detections on the 2 σ level and deserve closer investigation in the near future. Table 1 lists the integrated temperatures, derived CO luminosities and molecular gas mass estimates for all objects observed with SEST. The CO luminosities were determined, using

$$L'_{\text{CO}} = 23.5 \Omega_B D_L^2 I_{\text{CO}} (1+z)^{-3} (\text{K km s}^{-1} \text{ pc}^2),$$

(Solomon et al., 1992), where Ω_B is the telescope beam (45"). The luminosity distance D_L was calculated assuming $H_0 = 75 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and $q_0 = 0.5$. All upper limits are based on 3σ antenna temperature limits and a mean linewidth of 280 km s^{-1} . To derive molecular gas mass estimates, a conversion factor $\alpha = 4M_\odot (\text{K km s}^{-1} \text{ pc}^2)^{-1}$ was applied (Evans et al., 2001; Scoville et al., 2003, and references therein).

In the case of HE1029-1831 the BIMA survey led to a detection of bright CO line emission in a compact region. The medium spatial resolution of $13.6'' \times 5.8''$ that was achieved in this antenna array configuration did not allow to resolve the source. This was achieved by follow-up PdBI observations in B and C configuration in Feb. 2002

and in A configuration in Mar. 2003. These observations revealed a strong association of the detected CO(1-0) and CO(2-1) line emission with the optical bar. In the position-velocity diagrams a strong velocity gradient across the bar indicates a bar-driven inflow of gas. The CO emission is consistent with a simple bar model. The CO(2-1)/CO(1-0) line ratio is estimated to be 0.7, which indicates subthermally excited, cold gas typically found in a disk. A detailed analysis will be presented in Krips et al. (in prep).

In Sept. 2005 we were able to observe further 15 objects from an extended HES list with the IRAM 30 m telescope simultaneously in CO(1-0) and CO(2-1). With the extended list, it is possible to restrict upcoming analyses of the molecular gas content and distribution of AGN hosts with $z < 0.06$ to HES objects and hence gain in homogeneity. With the greater sensitivity of the IRAM 30m telescope, the goal was to observe to a common L'_{CO} limit of $2.5 \cdot 10^8 \text{ K km s}^{-1} \text{ pc}^2$. These observations resulted in a total of 10 detections. A detailed analysis will follow in an upcoming paper (Bertram et al., in prep).

4. Conclusion

To get an unbiased result, no preselection based on IRAS flux densities was applied. Out of 13 observed IRAS sources we detected 5 in their CO mm-line emission resulting in a 40% detection rate. 2 of the 6 marginally detected sources are IRAS sources, too. Including them, the detection rate amongst the IRAS sources is approximately 55%. This is the same order of magnitude as found by Evans et al. (2001) and also comparable to the detection rate reported by Scoville et al. (2003). Out of a total of 39 observed sources the 5 detected IRAS sources represent $\sim 13\%$. This result indicates that not all QSOs/high rank Seyferts reside in gas rich hosts as suggested by Scoville et al. (2003). Only one of the detected QSO hosts is identified as an elliptical, four of them are identified as spirals, two of them as barred spirals. Among the remaining non-detections the percentage of ellipti-

Table 1

Measured ^{12}CO properties of members of the QSO sample obtained with SEST. The Objects marked with "*" show weak signals which need to be confirmed. For the upper limits a linewidth of 280 km s^{-1} was assumed. I_{CO} was determined for re-sampled spectra with resolutions given below.

Obj.	cz	spectral Res.	$I_{\text{CO}(1-0)}$	spectral Res.	$I_{\text{CO}(2-1)}$	L'_{CO}	$M(\text{H}_2)$
	$[\text{km s}^{-1}]$	$[\text{km s}^{-1}]$	$[\text{K km s}^{-1}]$	$[\text{km s}^{-1}]$	$[\text{K km s}^{-1}]$	$[10^9 \text{K km s}^{-1} \text{ pc}^2]$	$[10^9 M_{\odot}]$
HE 0003-5023*	10027	14.9	< 0.8	15.0	< 0.8	< 0.71	< 2.83
HE 0036-5133	8640	29.6	< 1.2	15.0	< 0.8	< 0.71	< 2.83
HE 0051-2420	16788	22.0	< 1.0	22.0	< 1.0	< 1.88	< 7.54
J005924.5+270332	13770	21.8	< 1.0	21.7	< 1.9	< 1.31	< 5.25
HE 0103-3447	17088	30.5	< 1.2	7.7	< 0.6	< 2.59	< 10.36
HE 0108-4743	7285	7.4	2.2 ± 0.1	7.5	3.8 ± 0.1	0.97 ± 0.04	3.87
J012345.8-584821	14095	15.1	< 0.6	15.2	< 0.8	< 0.92	< 3.68
HE 0122-5137	15589	30.3	< 0.8	15.3	< 0.8	< 1.64	< 6.55
HE 0224-2834	17940	15.3	< 0.3	11.6	1.3 ± 0.1	0.71 ± 0.05	2.85
HE 0323-4204	17388	30.5	< 0.8	15.4	< 0.8	< 2.06	< 8.25
HE 0336-5545*	17688	30.5	< 0.4	30.8	< 1.1	< 0.70	< 2.78
HE 0343-3943	12933	30.0	< 1.2	15.2	< 0.8	< 1.54	< 6.16
HE 0349-4036*	17440	15.2	< 0.8	15.4	< 0.4	< 2.02	< 8.09
J035818.7-612407	14264	43.6	1.3 ± 0.1	43.6	3.0 ± 0.1	2.02 ± 0.15	8.07
HE 0359-3841	17688	22.0	< 1.0	22.0	< 1.5	< 2.08	< 8.3
HE 0403-3719	16540	15.2	< 0.6	15.4	< 0.4	< 1.22	< 4.89
HE 0429-5343	11994	30.0	< 0.4	30.3	< 0.6	< 0.33	< 1.33
HE 0436-4717*	15889	30.3	< 0.8	15.3	< 0.4	< 1.69	< 6.78
HE 0535-4224	10493	14.9	< 0.6	15.1	< 0.8	< 0.52	< 2.07
J061320.8-324154	14990	21.9	< 1.0	21.9	< 1.0	< 1.58	< 6.33
HE 0853-0126	17930	22.1	< 1.0	22.1	< 1.5	< 2.14	< 8.56
J091609.5-621929	17178	22.0	< 0.7	22.0	< 1.5	< 1.30	< 5.21
HE 1013-1947	16413	21.9	< 1.0	21.9	< 1.9	< 1.82	< 7.27
J204409.7-104324	10312	10.8	< 0.9	21.5	< 0.9	< 0.75	< 2.99
HE 2211-3903	11906	30.0	1.9 ± 0.1	15.1	1.9 ± 0.1	2.1 ± 0.11	8.39
HE 2231-3722	12891	15.0	< 0.8	15.2	< 0.8	< 1.14	< 4.56
HE 2236-3621	17988	22.1	< 1.0	22.1	< 1.5	< 2.13	< 8.54
J230443.5-084108	14185	21.8	< 1.0	21.8	< 1.9	< 1.39	< 5.57
HE 2354-3044*	9198	29.7	< 1.2	30.0	< 1.1	< 0.80	< 3.2

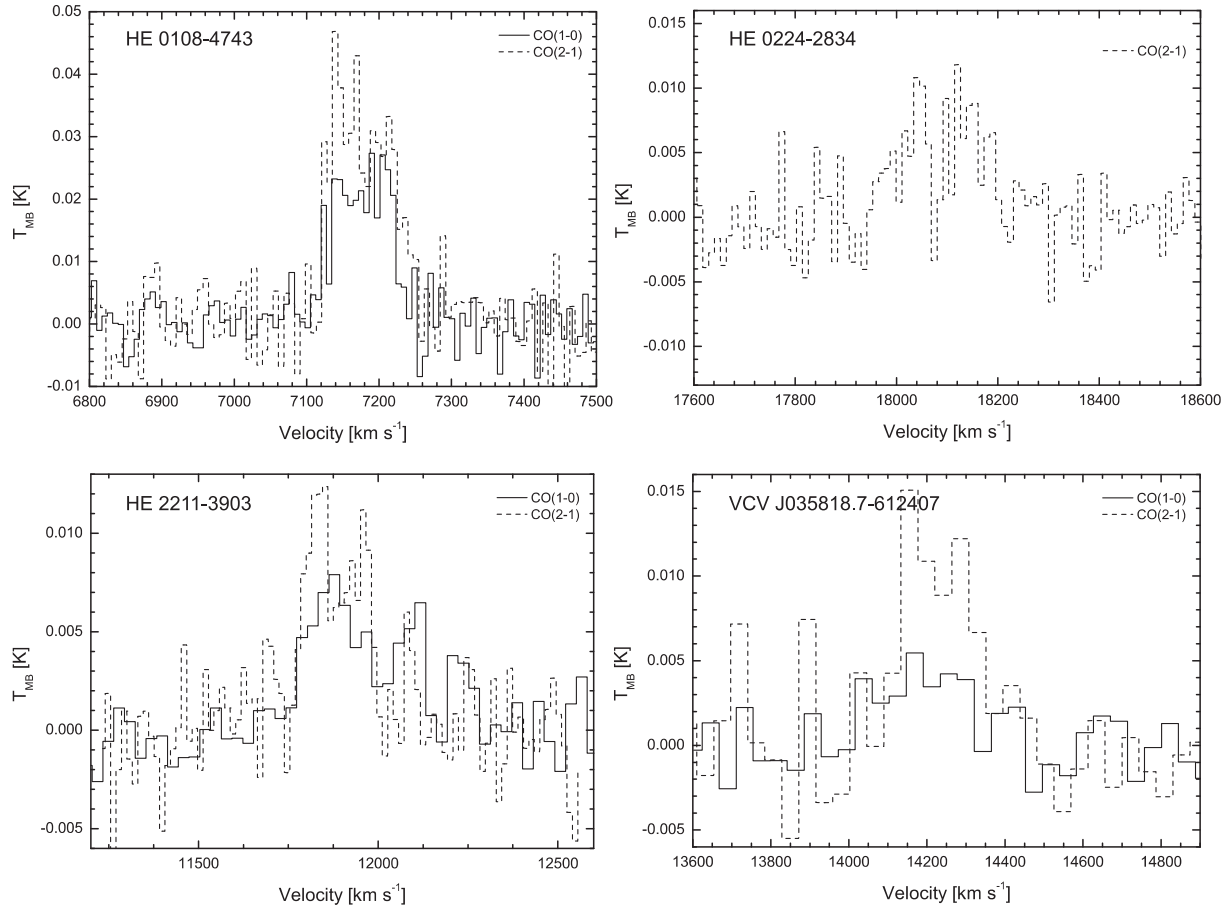


Fig. 1. ^{12}CO spectra of 4 members of the QSO sample detected with SEST.

cals (at least 26 sources) and S0 galaxies (at least 10 sources) is high. Only 12 are clearly identified as spirals, 9 of which are barred spirals. Although the 3σ upper limits for the molecular gas masses are high, this source classification is consistent with their preferential association with elliptical galaxies.

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